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## TRAINING MANUAL FOR FABRICATION OF PRINTED-CIRCUIT BOARDS

by

C. A. Nelson, T. W. Yannitell,  
and S. J. Rudnick

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PRINTED-CIRCUIT BOARDS

by

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July 1970

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# TRAINING MANUAL FOR FABRICATION OF PRINTED-CIRCUIT BOARDS

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## ABSTRACT

This manual describes the methods used for fabricating small lots of printed circuit boards in the ANL Electronics Division. Detailed step-by-step procedures are given. The purpose of this manual is to train personnel in the use of an existing printed-circuit fabrication facility. Information on the construction of a new facility or on the selection of equipment for a new facility is not included. Likewise, artwork preparation is not discussed.

## I. INTRODUCTION

### A. Purpose

This manual is intended to provide familiarity with the processes and procedures used by the ANL Electronics Division to fabricate printed circuit boards. The operations described are appropriate for one-of-a-kind and small-lot production. When many boards of the same kind are needed, it is usually more practical to employ the services of commercial board manufacturers set up for large-lot production.

In most cases, the processes described and the products mentioned are selected from many alternatives on the basis of peculiarities of our equipment and our past experience. They are not necessarily optimum, but they have suited our requirements.

This report is a training manual describing the operation of an existing printed-circuit fabrication facility. Criteria for the construction or selection of equipment for a new facility are not included. The step-by-step description of procedures begins with the photographing of a Mylar master and ends with a board ready to be trimmed and drilled.

### B. Darkroom

Each printed-circuit board begins with a "taped" and lettered Mylar master. The master is a layout, indicating which areas of the finished board

are to be copper and which are to be bare. In the darkroom, the Mylar master is photographed and the photographic film is developed in order to obtain the negative(s) that will later be used to fabricate boards. A camera, safelight, developing trays and tanks, and chemical storage cabinets are among the equipment found in this area. This darkroom should be just what the name implies, a dark room. This allows light-sensitive films to be handled in the open room without being exposed. To ensure the best results, the room must be kept clean and dust free.

#### C. Printed-circuit Room

The printed-circuit room contains all the equipment necessary for the fabrication of printed-circuit boards (except for cutting them to size, which is done in the shop). First, the copper-clad laminate from which the boards are made is cleaned and coated with a photosensitive resist. This resist is an organic resin, which is soluble in developer, but can be made insoluble by exposure to blue-ultraviolet light. It is advisable to process many boards or sheets of popular size to this point and store them for later use in a cool and dark place. Having presensitized boards available can reduce the lag time from receipt of a rush order to its completion.

The actual printing is done by exposing the boards to an ultraviolet light source through a photographic mask (the negative obtained from the darkroom) which protects unwanted areas of copper from "seeing" the light. Next, the image is developed, removing the unexposed resist and leaving the exposed resist to protect the underlying copper from subsequent etching. The unwanted copper is then removed in the spray etcher by the corrosive action of a ferric chloride solution. Finally, the remaining resist is removed and the copper surfaces tin-plated.

To reduce the handling time, many boards or sheets of boards can be processed in batches through each step in the fabrication process.

#### D. Housekeeping

Good results in the darkroom and in the printed-circuit room depend upon a clean and dust-free environment. Chemicals, dust, or even perspiration may cause spotting on negatives, and unwanted specks on a finished printed-circuit (PC) board. A routine for cleaning the floors, equipment, and the various surfaces should be established. The floor should be swept at least once a day (but not just before handling film) and be sponge-mopped once a week. All surfaces and dust-collecting ledges should be washed once a month.

#### E. Safety

Most of the chemicals used in both the darkroom and the printed-circuit room are potentially hazardous. This should be kept in mind at all

times. Neoprene gloves should be worn to prevent photographic developer, glacial acetic acid, photo resist, photo-resist thinner, trichloroethylene, ferric chloride, hydrochloric acid, stripper, or tinning solution from coming in contact with the skin. These chemicals can be especially hazardous if spilled on clothing. Clothing should be protected with a rubber or plastic apron and should be replaced immediately if contaminated.

The bottles and caps of containers should be rinsed and dried after use. Any chemicals spilled on table tops or floors should be wiped up and rinsed. A few unnoticed drops of acetic or hydrochloric acid spilled on the edge of a bench can get on clothes and cause serious trouble. For this reason, clothes should be changed every day.

When pouring or mixing any of these chemicals, wear a face shield. Avoid breathing any fumes. Glacial acetic acid, photo resist, photo-resist thinner, trichloroethylene, and the stripper should be mixed and used in or near the fume hood.

Keep all containers labeled. Keep all acid bottles in rubber carriers except when in use.

Further information on the toxic and injurious effects of these chemicals appears in Chapter 7 of Safety in the Chemical Laboratory by Dr. H. A. J. Pieters, Academic Press Inc. (1951).

## II. PROCESSING THE PHOTOGRAPHIC FILM

### A. Exposing

Tape the Mylar master to the backlighted copyboard in front of the lens, as shown in Fig. 1. Set the camera to the reduction marks on the camera bed corresponding to the required reduction, usually 4:1 or 2:1. Remove the lens cap, and set the exposure time on the timer for the shutter release. The exposure time is usually set for about 16 sec but may have to be adjusted as discussed in Section IV.B. Adjust the exposure time so that a good image is developed at the proper development time. If the negative is too dark when developed for the proper time, reduce the exposure time (and vice versa for a light negative).



Fig. 1. Taping a Mylar Master to the Copyboard

Adjust the vacuum back to correspond to the size of film being used. Set the lens for  $f/32$  for regular Ortho films. Turn off the room lights, and turn on the proper safelight (red for Ortho film, green for Pan film).

If the film to be used has recently been refrigerated, open the box and allow time for it to reach room temperature and for all condensed moisture to evaporate before breaking the seal on the inner package. Remove one sheet of film from the box, and put the lid back on the box. Open the vacuum back, as in Fig. 2. Place the film, the lighter side up,



Fig. 2. The Camera Film Board

on the vacuum back, and position it so that the film covers the vacuum grooves for that size film. The grooves should fit just inside the perimeter of the film on all edges. Turn on the vacuum pump, and make sure the film is lying flat against the back. Now gently close and lock the back. Turn on the backlight behind the Mylar master, and start the shutter-release timer. When the timer has cycled, turn off the backlight and open the film back. Turn off the pump, and remove the film. Do not turn on the room lights when an undeveloped negative is exposed. The film is now ready to be developed.

The "two-color separation" process allows a single two-color taped Mylar to be used to obtain the two different negatives corresponding to the two sides of a board. The red and blue separation is accomplished by exposing one sheet of Pan film

using a red lens filter and exposing another sheet of Pan film using a blue lens filter. The filter holders screw into the lens. Be sure to use the green safelight during this process. With the red filter, set the lens to  $f/32$ ; for the blue filter, use  $f/22$ . Use the red filter to register the blue lines, and the blue filter to register the red lines. Use the larger aperture (smaller  $f$  number) for the blue filter because the film is less sensitive to the blue color. The different  $f$  stops for the different filters allow the two films to be developed for equal times.

If the reduction marks on the camera bed are used, the focusing is ordinarily preset. Optional focusing can be done visually by removing the film back and letting the image focus on the ground glass (hinged on top of the camera) when it is put in place of the film back. Do the focusing with

the lens set at the largest aperture (smallest  $f$  number for brightest image). Any focusing will alter the size of the image, so both front and back must be moved to attain proper focus and size in most cases. When focusing is completed, reset the aperture.

A Mylar master is normally a positive of the desired printed-circuit board; i.e., the taped lines represent copper conductors. When the master is photographed, the result is a negative which is used when exposing a board. If, however, the Mylar master is a negative of the desired board, as is usually the case for the ground-plane side of a double-sided board, an extra step is required. The Mylar master is photographed, and the resulting film is processed in the usual manner. The film obtained is a positive of the desired printed-circuit board. Since a negative is required to expose the board, a contact print must be made. Place the positive upside down on the glass of the contact printing frame, and place an unexposed film light-side down over it. Be sure, to place the positive to be photographed upside down because, when the negative obtained is eventually used to contact-print the sensitized board, its emulsion side should be touching the board. Since this requires handling of unprocessed film, the room must be dark. Clamp the printing-frame cover on. Turn the frame over and expose the film for about 1 or 2 sec. Remove the film and process it in the usual manner, except that the progress of development must be checked visually.

## B. Developing

Various sizes of film are required for different boards. For 8- x 10-in. film the most convenient process, the tank method, can be used. When using tanks, mount each film in a film holder, as shown in Fig. 3. As many as six sheets of film can be developed at one time. If the negative must be larger than 8 x 10 in., use tray development. Only one sheet of film may be developed at a time using the trays.

The developing process is simple. The image is developed and then fixed in three basic steps:

1. Immerse the film in Kodolith developer for about 2 min.

Agitate the film for 10 sec every 30 sec, whether in trays or in tanks. In a tray, agitate by slowly rocking the tray. In the tank, agitate by lifting the

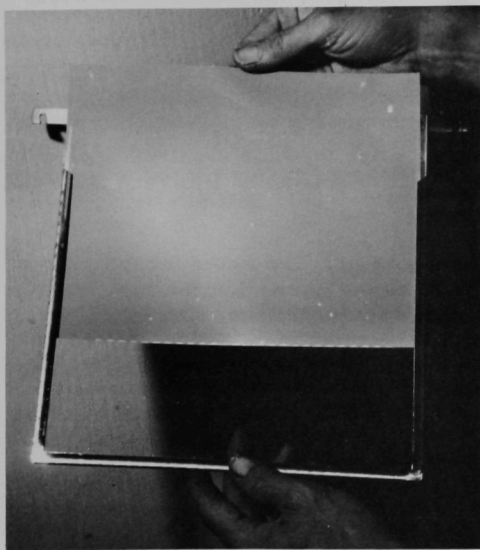


Fig. 3. Inserting Exposed Film in a Film Holder

film holder slightly as in Fig. 4. The precise development time varies with the age and temperature of the solution. Inspect the developing image visually to determine when development is complete. When using the tanks,

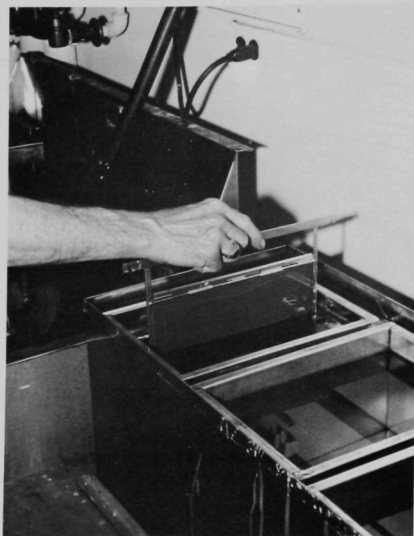


Fig. 4. Developing the Film

film, as determined by visual inspection. Remove the film, and allow the excess fixer to drain back into the tank.

Now wash the film in clear water. The water for the wash should be about the same temperature as the fixer. Let the film remain in the water (which is continually changing) for at least 10 min.

Hang the film to dry in a dust-free place, such as the forced-air drying box, shown in Fig. 5.

### C. Registration

When a two-sided board is exposed, a negative must be in contact with each side of the board. The two negatives must be in register. Two methods of registration are as follows:

1. Place one negative upside down on a light table. Make sure there is at least  $1\frac{1}{2}$  in. from one edge of the circuit to the adjacent edge of the film (later referred to as the reference edge). Cut the second negative

make sure that the floating lids are in place after the processing is completed. This increases the life of the solutions by decreasing the oxidation rate due to exposure to air and also keeps out dirt and dust. If trays are used, use new solutions of developer, stop bath, and fixer each day. Remove the film from the developing solution, and allow the solution to drain over the developer tank for about 5 sec.

2. The stop bath stops the developing action and prepares the film for the fixer bath. Immerse the film in the stop bath, and agitate for one-half minute. Then drain the film over the stop bath for about 5 sec.

3. Immerse the film in the fixer bath. Agitate the film every 30 sec for 10 sec. Continue for twice the time required to clear the



Fig. 5. Drying a Negative

so that, when it is placed right side up and the hole patterns are in register with those of the first negative, the reference edge of the first negative protrudes  $1/2$  in. from the corresponding edge of the second negative. Carefully align the top negative to register with the bottom negative, and apply masking tape to both negatives at the reference edge to hold them together yet allow easy insertion of a board between them.

2. This method is a mechanical means of registration. The light table used when making the layout must be equipped with registration pins, and the Mylar sheets must be prepunched to fit the pins. The copyboard of the camera and the film board must be equipped with registration pins, and the film

must be punched before exposure. Once exposed and developed, the two negatives will automatically have their image patterns in register with the punched holes. When both negatives are placed on a set of pins, their images will be in perfect register, and the negatives can then be taped together as described for method 1. This method has the advantage that visual registration is not necessary, but somewhat better control of environmental conditions may be required in the layout areas.

#### D. Filing

1. Store the Mylar masters in the drawing cabinet in numerical order, according to PC number. Do not stack them too high in the drawers, and do not fold them, roll them, or scrape them against anything. The air temperature and humidity in the storage area should be controlled. Before storing the masters of a two-sided board, fasten them together. Be sure that all sheets are marked with their PC numbers in accessible positions.

2. Using a label marker, mark the PC numbers on the negatives and films obtained in the intermediate steps, and store them in numerical order in the filing cabinet, as illustrated in Fig. 6.



Fig. 6  
Filing a Negative

### III. PHOTOETCHING PROCESS

#### A. Cutting

Printed-circuit boards are made of copper-clad laminated fiberglass impregnated with epoxy. The thickness of the base material, the copper weight, and the number of sides of copper for each board should be specified by the requisitioner. The material is ordinarily supplied in large sheets. Initially, the large sheets should be cut to dimensions at least 1 in. larger than the dimensions desired for the finished board. A sheet-metal shear, such as the one shown in Fig. 7, may be used. Alternatively, to reduce production time, sheets large enough to allow production of several boards at once can be cut.

#### B. Cleaning

The copper surfaces of the cut material must be free from oxidation and foreign material, and they must be thoroughly dry before the next step. Proceed as follows:

1. Scrub each board with the rotary scrub brush using cold water and Shipley scrubbing compound No. 11, as shown in Fig. 8. Use cold water to reduce oxidation of the copper.

2. When cleaning large boards, remove most of the water with the air knife.

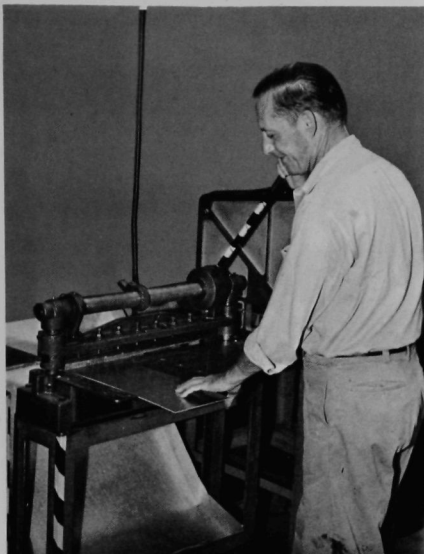


Fig. 7. Cutting Laminate Material

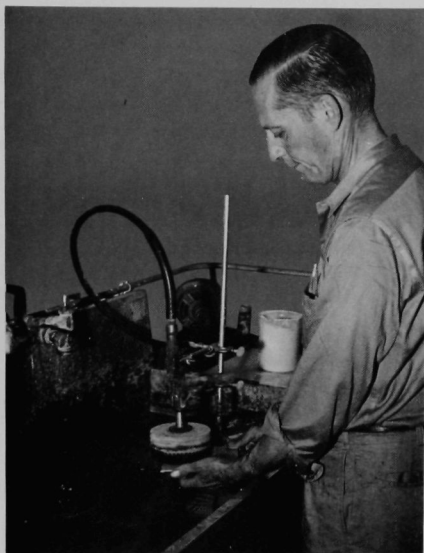


Fig. 8. Scrubbing a Board

3. Quickly dry the board by wiping with paper towels, as illustrated in Fig. 9, while cool air is blown on it by a fan.

4. Place the board on a wood holding rack (a notched two-by-four) at a distance from the scrubbing sink and drying area so that no water will be splashed on the board. Alternatively, the board may be placed on dry paper towels, as shown in Fig. 10. Blow warm air on it to complete the drying of the edges.

### C. Sensitizing

1. Holding the cleaned and dried board by a clamp or pliers at one edge, dip it into the container of Kodak Photo Resist (KPR), as in Fig. 11.

2. After removing the board from the resist, hang it up to air-dry in a hood with very little airflow. Hang it so that its bottom edge is approximately horizontal. This is most important for large boards. Do not use forced-air drying; it would cause the surface of the resist to dry and form a skin which would prevent complete drying.

3. When the entire surface of the board is dry to the touch (approximately 10 min), heat it with three 250-W infrared lamps for 20 min to complete the drying. Heat only one side of the board as the heat is readily conducted through to the other side. (See Fig. 12.)



Fig. 9. Hand-drying a Board

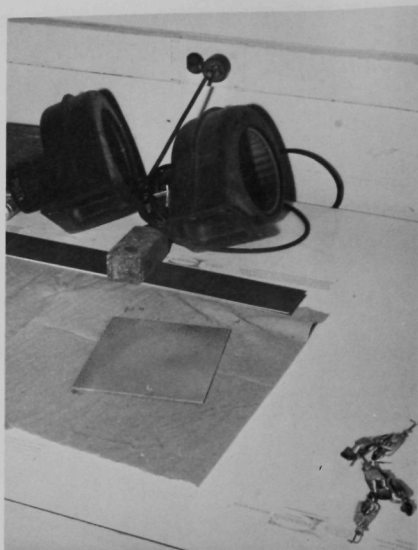


Fig. 10. Forced-air-drying a Board



Fig. 11. Dipping a Board in the Resist



Fig. 12. Heating Newly Sensitized Boards

4. Once the board is coated with resist, it is sensitive to light. Exposure to the lights in the PC room for more than 30 min may partially expose the resist. This would ultimately result in unwanted copper patches on the finished board. The coating is even more sensitive to fluorescent light and sun light. If the sensitized board is not to be used immediately, store it in a clean, dry, and, most importantly, dark place.

#### D. Exposing

A double-sided board is exposed in the printer with a negative in contact with each side, as in Figs. 13 and 14. The exposure timer should be set at 7 min. This is more than adequate. The area of the board which is exposed through the negative will be polymerized; that is, the molecules in the resist interlock so that they will not dissolve in the developer. The procedure for a single-sided board differs only in that the side without copper should be protected from exposure with two sheets of dark orange or black paper, as shown in Fig. 15. If this is not done, the resist will become polymerized. Polymerized resist on an epoxy surface is hard to remove.



Fig. 13. Inserting a Board between Two Negatives



Fig. 14. A Double-sided Board with Two Negatives in the Vacuum Frame of the Printer

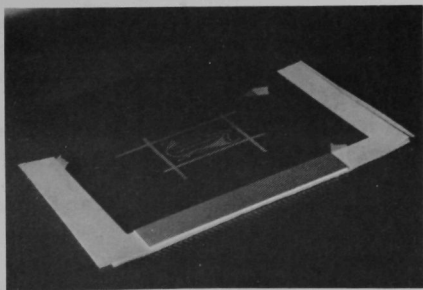


Fig. 15

A Single-sided Board in the Vacuum Frame



Fig. 16. Immersing a Board in the Developer Spray

ghosts are indications of resist-saturated developer. If the residue left on the board is not excessive, it can usually be removed by rinsing in a soft flow of cold water. Do not touch the resist while wet with developer, because it is soft and can easily be damaged.

#### F. Etching

The copper that is not protected by resist is etched away with a ferric chloride spray in the etcher:

1. Place the developed board in the etcher, as shown in Fig. 17, and set the timer for 2 min. When the etcher shuts off, inspect the board to see how the etching is progressing. If one side or one edge is etched far more than the other, turn the board over or around to even the depth of etch and proceed with step 2.

2. If the etching is not complete, reinsert the board and etch briefly. Repeat until all unwanted copper is removed.

3. Rinse the board, as shown in Fig. 18, being careful not to get water into the section of the apron that drains into the sump.

4. Using hot water, spray-rinse the board in the sink and hand-dry it.

#### E. Developing the Resist

After exposure and before development, the board is still light sensitive; therefore, be sure not to leave it exposed to room light for more than a total of 30 min. Lower the board through the developer (tri-chloroethylene--TCE) spray in the developing machine, and then slowly raise it up through the spray. (See Fig. 16.) Repeat three or four times. This dissolves and washes away the unexposed portions of the resist on the boards. If the developer is fresh, the board will dry satisfactorily very quickly; however, if the developer has much resist in it, a residue will be left on the surface of the board. Vertical lines, or closely spaced beads in a vertical line, or horizontal edges of the image that appear to have



Fig. 17. Inserting Boards in the Etcher



Fig. 18. Rinsing the Etchant from a Board

### G. Stripping

1. Allow 10 min for the board to air-dry to be sure that no water is carried into the stripper.
2. Soak the board in the stripper for 30 sec. (See Fig. 19.)
3. Remove the board from the stripper, and spray with high-pressure hot water.
4. With Shipley scrubbing compound No. 11 and a scrub brush, remove the remaining resist.
5. Rinse the board in cold water, and store it in Shipley Neutra-Clean solution for at least 2 min. The solution can be used as a holding bath in which to keep stripped boards while other boards are being stripped or tinned.

### H. Tin Plating

1. Remove the board from the Neutra-Clean. Rinse in hot water and place it in the tinning solution for 4 min. (See Fig. 20.)
2. Remove the board from the tinning solution, rinse it in a hot-water spray, and hand-dry. If the tin plate is dull, it can be improved by lightly wiping it with a Brillo pad, then rinsing and drying.



Fig. 19. Immersing a Board in the Stripper



Fig. 20. Tinning a Finished Board

#### IV. MAINTENANCE OF DARKROOM FACILITIES

##### A. Camera

The camera assembly, including the vacuum back, camera bed, and copyboard, should be kept dust and spot free. Clean the camera lens with a camel's-hair brush about once a month, and place the lens cap over the lens when the camera is not in use. If the lens has any residue remaining on it after brushing, clean the lens by rubbing it very gently with facial tissue folded several times. Remove dust from the bellows with a vacuum cleaner.

##### B. Developer

Kodalith developer comes in two packages, part A and part B, each sufficient for 1 gal of solution. To make stock solutions, mix the two parts separately with water. Slowly add each part of the two-part Kodalith developer unit to warm (100°F) deionized water in separate, properly labeled 5-gal bottles. Stir constantly as the powder is being added, and continue till completely dissolved. To make a working solution, mix together equal amounts of stock solutions A and B. The stock solutions, however, should be mixed one day before making a working solution. Three gallons of each stock solution should be made at a time. Add  $1\frac{1}{2}$  gal of each

stock solution to the  $3\frac{1}{2}$ -gal developer tank. This leaves  $1\frac{1}{2}$  gal of each for tray use. When tray processing is necessary, pour about 500 ml of each stock solution into the developer tray. Before using, leave the new working solution idle for at least 2 hr in the tank or 10 min in the tray. The stock solution containers (5-gal plastic bottles) should be rinsed before mixing a new solution or replaced if the residue cannot be removed. Store the stock solutions in a cool dark place. Once a working solution is made up, maintain its temperature at 68°F. To do this, circulate temperature-controlled water through the outer jacket of the process tanks or into the sink around the trays, if used. The life of the developer depends upon temperature, exposure to air, and the quality of the water used. This is why it is important to control the temperature, install the floating lids when not in use, and use deionized water to make the stock solutions.

Each time the developing solution in the tank is replaced, determine the proper exposure time for that solution. This is done by making a trial exposure for 16 sec and developing the film under the following "standard conditions":

1. Normal backlight intensity.
2. Lens on the camera set at f/32.
3. Film at room temperature when exposed.
4. Developer temperature maintained at 68°F.
5. Film agitated in the developer for 10 sec every 30 sec.

Note the time required to completely develop the film. If it is less than 2 min, reset the camera exposure timer to a shorter time; if more than 3 min, reset it to a longer time.

Replace the solution in the tank every week or whenever the exposure time required to meet the 3-min limit imposed above is more than 20 sec. The solution in a tray will last only one day.

### C. Stop Bath

The only chemical stocked for the stop bath is glacial acetic acid. The acid does not mix readily in water without stirring and has a very strong odor. DO NOT ATTEMPT TO SMELL THE ACID IN THE UNDILUTED FORM. Always wash off acid that has spilled or has come in contact with the skin.

In the fume hood, add glacial acetic acid slowly to room-temperature water in the ratio of one part of acid to 25 parts of water or 24 oz of acid to  $4\frac{3}{4}$  gal of water. Since the acid comes in a glass container, keep it in a

rubber carrying bucket when not in use and handle it gently. When handling this acid, always wear rubber gloves, a rubber or plastic apron, and a face shield. As a safety measure, the acid may be transferred to a plastic bottle in the fume hood. Be sure to mark the new bottle properly. Replace the stop bath whenever the developer is replaced.

#### D. Fixer

The fixer bath clears the opaque backing on the film and hardens the image. The Edwal Quick-Fix liquid concentrate is used for this bath. For a 3-gal solution, mix one bottle (81 fl oz) of concentrate with  $2\frac{1}{4}$  gal of 70°F water. While stirring, slowly add 12 oz of Edwal Hardener. Discard the bath whenever the clearing time rises above 1 min. The concentrate can be stored indefinitely.

#### E. General Comments

Specific chemicals are mentioned above only because they have been used satisfactorily in the past. This is not to infer that other chemicals are not to be used or tried.

The life of most chemical solutions depends upon the quality of the water used. If the water has a high mineral or foreign chemical content, the life of the developer will decrease. The life of the developer is also highly dependent upon its exposure to air. The developer will oxidize quickly when air is present. The life of separate stock solutions of parts A and B will be five times as long as when they are mixed for use. Development times vary accordingly. For example, the "normal development time" for the film in fresh developer should be 2 min, but it will be about 3 min when the solution is a week old.

THINK CLEAN. Make sure that all containers are thoroughly cleaned periodically or when solutions are mixed or replaced. This means using soap and water and thoroughly rinsing trays and bottles.

All liquids used in the process are to be at 68°F. When using trays, make up a fresh solution of developer, stop bath, and fixer every day. When using the film tanks, be sure the floating lids are in place whenever films are not being processed. This keeps air and dirt away from the solutions.

### V. MAINTENANCE OF PHOTOETCHING CHEMICALS AND EQUIPMENT

#### A. Copper-clad Laminate

1. Keep the laminate material in the storage rack until needed.

2. Do not allow the material to come in contact with silicone compounds such as are found in some hand creams, sight savers, and heat-sink compounds.

3. Protect the copper surfaces from damage.

#### B. Scrubber

1. Clamp the scrubber securely to its mount.
2. Replace the nylon brush of the scrubber when the bristles are worn to a length less than  $5/16$  in.
3. Remove the residue collected in the sink every week.

#### C. Resist

1. Except when being used, keep the resist covered to reduce exposure to light, water, and dust.

2. Do not allow any water to mix with the resist.

3. Place paper towels in the hood in such a way as to catch the resist that drips from the boards. Dispose of the towels in a safety waste can at the end of each day.

4. Remove all resist drippings from the cabinet each day. TCE can be used as a solvent.

5. To make up the resist solution, fill the tank with Kodak Photo Resist (KPR) to a level 4 in. from the top. Add 8 oz of KPR thinner. A 6- x 16-in. two-sided board should then be coated and processed through the developing step. Examine the image near the edge of the board that came out of the resist last. (Ignore the final  $1/2$  in.) If it is swollen or ill-defined, the resist in the tank is too thick and thinner should be added. If the image is clear, process the board through the etching step. If the resist near the edge of the board that came out of the resist first has been broken down or removed due to the etching action, the resist in the tank is too thin. (Ignore the first  $1/2$  in.) Add resist to the tank to thicken it. After initial makeup and each adjustment to the solution, allow 2 hr for it to stabilize, and then process another sample board as just described until the solution viscosity is optimum. Once the proper solution viscosity is determined, it can be easily checked with a Zahn Cup. Do this periodically so that the viscosity can be held close to its optimum value.

6. Do not stir or agitate the resist in the tank at any time. This might cause foreign material which has settled to the bottom of the tank to contaminate the coating on the boards. Maintain the level by adding resist when needed.

7. Provided the viscosity is maintained, no water is admitted, and the room-air humidity is kept below 50%, the life of this solution is expected to be many months at least. However, if trouble is experienced and the cause is suspected to be bad resist, fill the small (8- x 10 in.-deep) tank with fresh resist and use it to coat two small boards (6 x 6 in.). Also coat two of the same size boards using the resist in the large tank. Expose them with different negatives so that they can be easily identified. Process them all through the etching step, and compare the results. If it is apparent that the new resist removed the fault and the fault cannot be corrected by adjusting the viscosity, dispose of the old resist and make a new solution. Siphon the spent resist into a 5-gal plastic bottle. Reclamation personnel will dispose of it.

#### D. Printer

1. Before each loading, blow out the plastic drawer of the printer with compressed nitrogen or wipe it with a wet towel. A light placed under the bench (25 W or smaller) helps make any specks visible.

2. Replace the plastic in the drawers when imbedded with dirt.

3. When the exposure time must be increased to polymerize the resist adequately, replace the lamps. To check the exposure time, use a Kodak step tablet once a month on a sample board.

#### E. Spray Developer

1. Be careful not to drop a board into the spray-developing machine, because it could puncture the bottom.

2. Drain the TCE into a 5-gal plastic bottle when it no longer looks clear in the bottom of the tank or when it leaves a residue on the boards. Reclamation personnel will dispose of it.

3. Change the filter on the machine every 3 months.

4. Handle the TCE cautiously! If spilled on the floor, it would dissolve the tile. If allowed to contact the skin, it would dissolve the natural oils. Avoid breathing the vapors of TCE.

#### F. Etcher

1. Occasionally, water will not drain from the apron. This is due to copper precipitating in the drain and blocking the flow. This can be cleared by pouring about 8 oz of reagent grade HCl into the standing water. This acid is dangerous and should always be kept in a carton or rubber bucket. Wear eye protection, an apron, and neoprene gloves. Avoid breathing the fumes.

2. It is normally recommended to replace the etchant when it has a concentration of 10 oz Cu/gal. This is 350 oz in the "800" machine. If 2 oz Cu is being etched, this corresponds to 175 sq ft. Since most of our double-sided boards do not have much copper etched from the ground-plane side, that side can be neglected when calculating the total area. It is impractical to wait until the limit of 10 oz Cu/gal is reached before changing the etchant, however, because as the limit is approached the copper precipitate rapidly clogs the spray nozzles and the drain. If it is necessary to use the etchant with a high copper content, add 1 pint of HCl. This allows the etchant to hold more copper in solution.

3. Each Friday, drain the etchant into an empty drum. Always turn off the main power first. If the drain is clogged, clear it by taking the end of the hose out of the drum and pouring 1 pint of water into it and back flushing it into the etcher by alternately lifting and lowering the hose three or four times. If this does not work after two attempts, cautiously pour 8 oz of HCl into the hose and allow it to stand, or repeat the pumping action just described for 2 min.

4. After the machine has been drained, remove the top cover and rinse it and the inside of the machine. Refill the machine with warm water, and replace the cover. Turn the heater power switch off and the main power on. Turn on the spray, and observe the operation of the nozzles. Record which nozzles are not spraying evenly. To observe the lower nozzles, turn the upper ones off with the valve in the back of the machine. Open the valve, and turn the machine off. Drain the water into the drum, but be careful not to cause the drum to overflow. Remove the clogged nozzles, and dislodge any loose material. Put them in a beaker of 38% HCl until they are free of all copper residue. Use just enough HCl to cover them. Before replacing the nozzles, fill the etcher with water, replace the cover, and turn on the spray for 1 min. Drain most of the water from the sump, leaving just enough to cover the copper residue in the bottom. Remove, clean, and replace the filter in the rear of the machine. Use HCl if necessary to dissolve copper. Replace the filter, the nozzles, and the spray-compartment cover. When replacing the nozzles, be very careful not to strip the threads. They should be just barely tight, and the grooves in their heads should form a 45° angle with the feed pipe. Pour one bottle of HCl through the apron compartment that drains into the sump and leave it overnight to dissolve the copper residue. In the morning, drain the sump and refill it with ferric chloride. Reclamation personnel will dispose of the waste in the drums.

#### G. Stripping Solution

The stripping solution is either PC & E 400 (Photofabrication Chemical and Equipment Co.) used full strength of Shipley No. 77 mixed 1:4 with TCE. Replace every 3 months. Siphon the spent solution into a 5-gal plastic bottle. Reclamation personnel will dispose of it.

## H. Holding Solution

To make up the holding solution, add 4 lb of Shipley Neutra-Clean No. 7 dry concentrate to 5 gal of hot water. Add water to maintain the level as needed. Replace the solution every month.

## I. Tinning Solution

The tinning solution is Shipley LT-26. In the Shipley specification sheet, PI-26D, the mixture to use is called "Fast Tin."

1. Add  $1\frac{1}{2}$  qt or 141 ml of reagent grade HCl to  $4\frac{1}{8}$  gal of deionized water. Caution: Add the acid slowly while the water is at or below room temperature. Wear goggles, gloves, and a rubber or plastic apron. Do not breathe the fumes.

2. Heat the acid solution to 180-200°F (80-93°C).

3. While stirring, slowly add 13 lb of LT-26 salts. If the solution clouds up or if the salts tend to stay on the bottom without dissolving, the solution may be cooling off too much. Allow it to come back to temperature before adding more salts.

4. Set the Variac at 65. This will keep the operating temperatures at 185°F (85°C). The operating range is 175-200°F (80-93°C).

5. Turn off the tinning solution if it will be idle for more than 24 hr, such as over a holiday or weekend.

6. The tinning solution will plate  $35 \times 10^{-6}$  in. of tin on copper surfaces immersed for 4 min.

7. After plating 90 sq ft (13,000 sq in.), the deposition rate decreases. The solution can be replenished by adding 5 lb of LT-26 salts. This may be done a maximum of three times if necessary.

8. Keep the solution covered as much as possible, and maintain the level by adding deionized water when needed. Do not add more HCl.

9. To dispose of a spent solution, siphon it into a 5-gal waste bottle while still hot. Reclamation personnel will dispose of it.

## VI. LIST OF MATERIALS

The following is a list of the chemicals and materials used at ANL for printed-circuit fabrication. ANL stock numbers or sample purchase order numbers are given.

Developer: Kodalith Developer	15-2357-00
Short stop: Glacial Acetic Acid	03-0061-00
Fixer: Edwal Fixer	15-2586-00
Film: Kodalith Ortho PB type 3	
8 x 10 in.	15-2556-50
10 x 12 in.	15-2556-35
12 x 18 in.	15-2556-55
Film: Kodalith Estar Base Panchromatic, 8 x 10 in.	
Scrubbing compound: Shipley No. 11	PO 678306
Photo resist: Kodak Photo Resist (KPR)	15-5071-00
Photo-resist thinner: KPR Thinner	15-6673-00
Developer: Trichloroethylene	03-5205-00
Etchant: Hunts Fast Etch Ferric Chloride	03-2803-00
Hydrochloric acid	03-0180-00
Stripper: Shipley Stripper No. 77 or Photofabrication	
Chemical and Equipment Co. Stripper No. 400	PO 567692
Neutra-Clean: Shipley Neutra-Clean No. 7	PO 660213
Tinning solution: Shipley LT-26	PO 678306
Paper towels	08-4795-00
Scouring pads	08-3695-00
Rotary scrub brush	PO 659606
Hand scrub brush	08-0900-00
Neoprene gloves	15-3630-00
Copper-clad laminate, printed-circuit material, all G-10:	

Size, in.	Thickness, in.	Copper Weight, oz	No. of Sides	
$4\frac{1}{2} \times 7$	1/16	2	1	06-0080-05
$4\frac{1}{2} \times 7\frac{3}{4}$	3/32	2	1	06-0080-10
$4\frac{1}{2} \times 7\frac{3}{4}$	3/32	2	2	06-0080-15
21 x 36	1/16	2	1	06-0080-20
21 x 36	1/16	2	2	06-0080-22
21 x 36	1/16	1	2	06-0080-23
21 x 36	3/32	2	2	06-0080-25
21 x 36	3/32	2	1	06-0080-30

## VII. SUMMARY OF SCHEDULED MAINTENANCE

### A. Daily

1. Wash developer, stop bath, and fixer trays.
2. Wipe up resist drippings.
3. See that the floors are swept.

B. Weekly

1. Mix fresh developer and stop bath for tanks.
2. Clean scrubber sink.
3. Drain and clean etcher.
4. See that the floors are mopped.

C. Monthly

1. Clean camera lens.
2. Check printer exposure time.
3. Replace holding solution.
4. Wash all dust-collecting surfaces and ledges.

D. Quarterly

1. Clean camera bellows.
2. Replace spray-developer filter.
3. Replace stripping solution.

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ARGONNE NATIONAL LAB WEST



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